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AN EXPERIMENTAL STUDY OF TWO METHODS OF INDEXING TACTICAL IMAGERY

by RICHARD S. LAYMON.

System Development Corporation

JULY 1966

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NOTICES

FOREWORD

The SURVEILLANCE SYSTEMS RDT&E PROJECT has as its objective the production of scientific research data bearing on the extraction of information from imagery produced as a result of aerial reconnaissance and the efficient storage, retrieval, and transmission of information within an advanced computerized image interpretation facility. Emphasis is on the men within the facility and their interactions with equipment in performing their functions. Research results are used in future systems design and in the development of enhanced techniques and procedures for all phases of the interpretation process within the data reduction facility.

The MAN-COMPUTER FUNCTIONS Task is one of four research Tasks established to focus on operationally meaningful segments of the surveillance system. Among the specific objectives of the Task is the development of an integrated system for the organization and presentation of reference information. The present study compares two methods of indexing reference materials for the use of image interpreters in an integrated image interpretation facility.

The experimentation reported was conducted jointly by personnel of the Advanced Systems Division, System Development Corporation, and personnel of the U. S. Army Personnel Research Office. Mr. Arthur Nelson, Federal Systems Division, IBM, who participated in a related study conducted jointly with U. S. APRO research personnel, gave substantial assistance in developing the concept of the study and interpretation of the results.

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Technical Research Note 176

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AN EXPERIMENTAL STUDY OF TWO METHODS OF INDEXING TACTICAL IMAGERY

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AN EXPERIMENTAL STUDY OF TWO METHODS OF INDEXING TACTICAL IMAGERY

BRIEF

Requirement:

To evaluate two indexing methods--graphic and textual--as aids to retrieval of stored rolls of tactical imagery in a tactical image interpretation facility. The study was designed to contribute to the broad objective of developing maximally effective procedures for organizing and presenting reference materials in a computer-based image interpretation system.

Procedure:

Image interpreters were trained in the use of area-oriented graphic and textual indexes to tactical imagery on roll film. Experiments were then conducted in which the interpreters were required to obtain from indexes the accession numbers of rolls of imagery containing coverage for a given area. Interpreter performance with graphic and textual indexes was compared. The problems were designed to require use of the indexes in a variety of experimental conditions including variation in the size of an area and inclusion of an area in one map or in two maps. Order of presenting the indexes and the problem conditions were balanced. Time taken to reach a correct solution was recorded to the nearest second.

Findings:

With the textual index, interpreters took less time on the average when the indexed areas were small. With the graphic index, they took less time when the areas were large. The longer time taken to find the desired imagery for large areas with the textual index appeared due to the recording and analysis tasks required when using the textual index under those conditions.

Utilization of Findings:

A graphic index would be useful in a manual image processing system where a major requirement is to obtain image coverage for large geographical areas.

A textual index which utilizes a fine grid to quantify area coverage would be useful in a computerized tactical image processing system where the major requirement is to obtain image coverage of targets confined to small areas.

Where reference coverage is needed for both small and large areas, a textual index might serve as a broad screen to isolate sets of prior coverage imagery, which could then be more thoroughly searched (by graphic index) for the desired detailed coverage.

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AN EXPERIMENTAL STUDY OF TWO METHODS OF INDEXING TACTICAL IMAGERY

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BACKGROUND

A Tactical Image Interpretation Facility (TIIF) must incorporate stored reference materials to assist the image interpreter in interpreting new imagery. These stored reference materials include maps, tactical target illustrations, keys, image interpreter reports, and rolls of tactical imagery containing prior cover. These materials must be organized so that the interpreter can easily and quickly determine the availability and location of specific reference items.

An extremely important factor in the organization of reference material is the indexing system introduced to represent in a concise manner the contents and location of stored material. A concept for indexing reference materials within a TIIF was developed in a related study effort.[1] The results of this analysis are briefly summarized:

> The TIIF index should be designed to provide an image interpreter means of locating a specific reference item by source data (date, sensor identification) or by selected content information. Each type of reference material should have its own index. For materials indexed at a central facility (maps, keys, tactical target illustrations), existing indexes should be adapted or modified for a TIIF. For reference materials that are generated within a TIIF (prior imagery cover, interpreter reports), the index information should be generated entirely within a TIIF.
>
> Analysis of the requirements of an index for locating and retrieving desired rolls of prior imagery indicated that retrieval of imagery would be facilitated if the interpreter searched for coverage on the basis of area rather than source data. Area was therefore chosen as the primary basis for indexing.

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[1] Arthur Nelson, Kenneth McClure, and John Polgreen (IBM), and Robert Sadacca (USAPRO). Organization and Presentation of Image Interpretation Reference and Auxiliary Information. U. S. Army Personnel Research Office Technical Research Note 173. June 1966. Research performed under contract to the Department of the Army by the Federal Systems Division, International Business Machines Corporation.

The TIIF area index for imagery specifies a world-wide grid containing uniformly equal search areas. Initially, a one-degree square area was proposed as the unit search area since the one-degree area is regularly used by several military agencies. However, a study of TIIF imagery handling requirements indicated that a one-degree square was too large. For this reason, the area of the Army Map Service (AMS) 1:50,000 scale map (approximately 12 miles by 12 miles) was chosen as the basic search area. Each basic search area is therefore identifiable by the AMS map coordinates or the AMS map area name.

In proposed reference systems, information about each roll of imagery received--or stored--would be encoded for manual or computerized access. Two feasible methods of encoding area information in a index of prior cover were considered feasible in a TIIF. One method uses a graphic plot of the image area coverage of each mission as the primary index data (see Figure 1). This plot would be keyed to a map base. The other method represents imagery coverage by letters and/or numbers. A relatively fine grid or matrix whose elements are characterized in some systematic fashion by a series of letters and numbers is superimposed on a map area. Image coverage is represented on an index record by letter/number combinations of grid areas covered by the imagery. Figure 2 illustrates this type of index record.

The present experiment was conducted to evaluate the two methods for speed and accuracy in locating rolls of referenced imagery in a TIIF.

TIIF INDEXING TASKS

Three primary tasks must be performed in relation to an index in an image interpretation system: (1) indexing the imagery, (2) searching the index for information about the content and location of the stored imagery, and (3) updating the index as better or newer imagery becomes available. The search task is especially important because of the critical need for rapid location of reference materials during Hot and Immediate reporting by TIIF personnel. There is also need for fairly rapid access to reference materials for orientation prior to a mission. Both initial indexing and updating will probably be accomplished during lull periods in a TIIF. The search task has therefore been singled out as the focus of the present study.

The search task begins when the interpreter receives a requirement to determine if previously obtained and stored imagery contains information pertinent to the present mission or a requirement to detect changes of military significance between newly acquired imagery and imagery in storage. The requirement may come from G-2 or the local officer-in-charge or non-commissioned officer-in-charge. The requirement is incorporated on a map overlay, if an overlay has not already

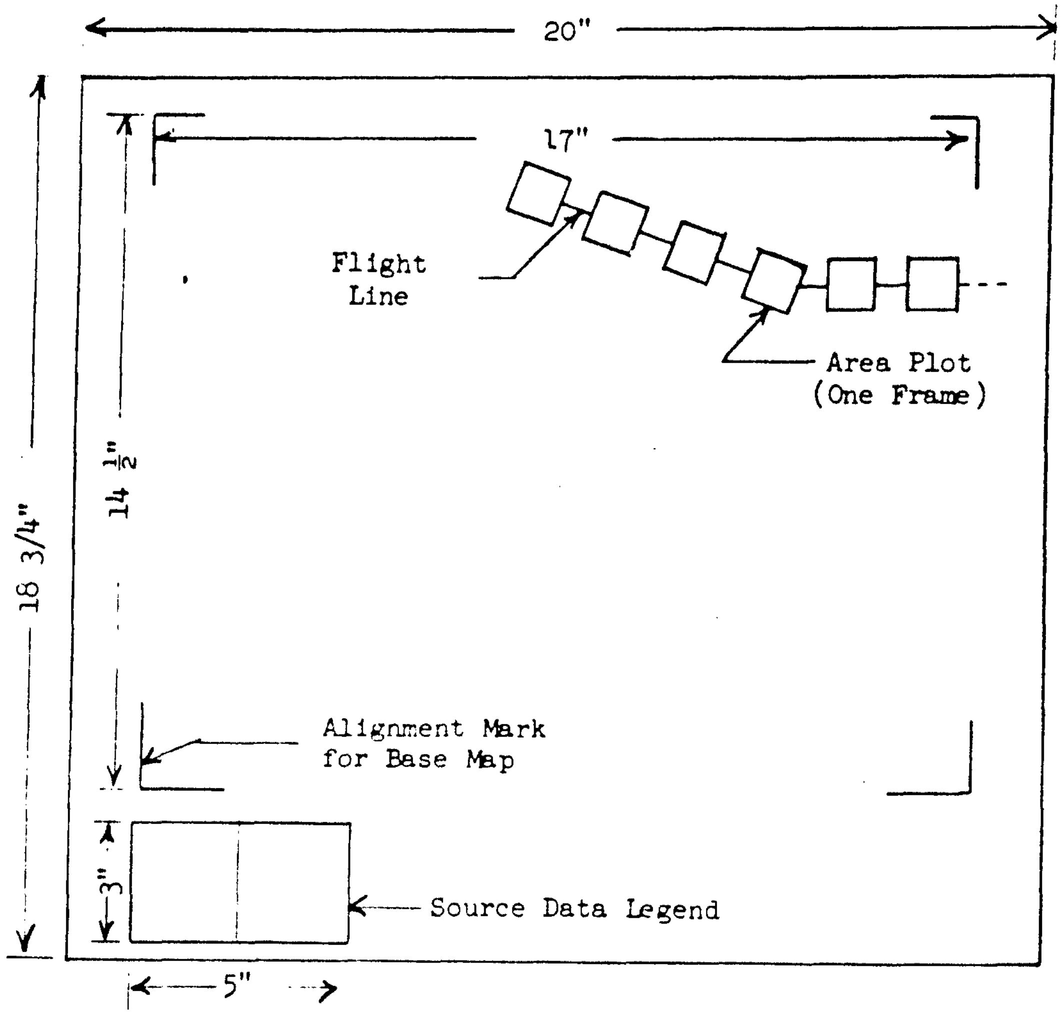

Figure 1. Example of a Graphic Index Record.

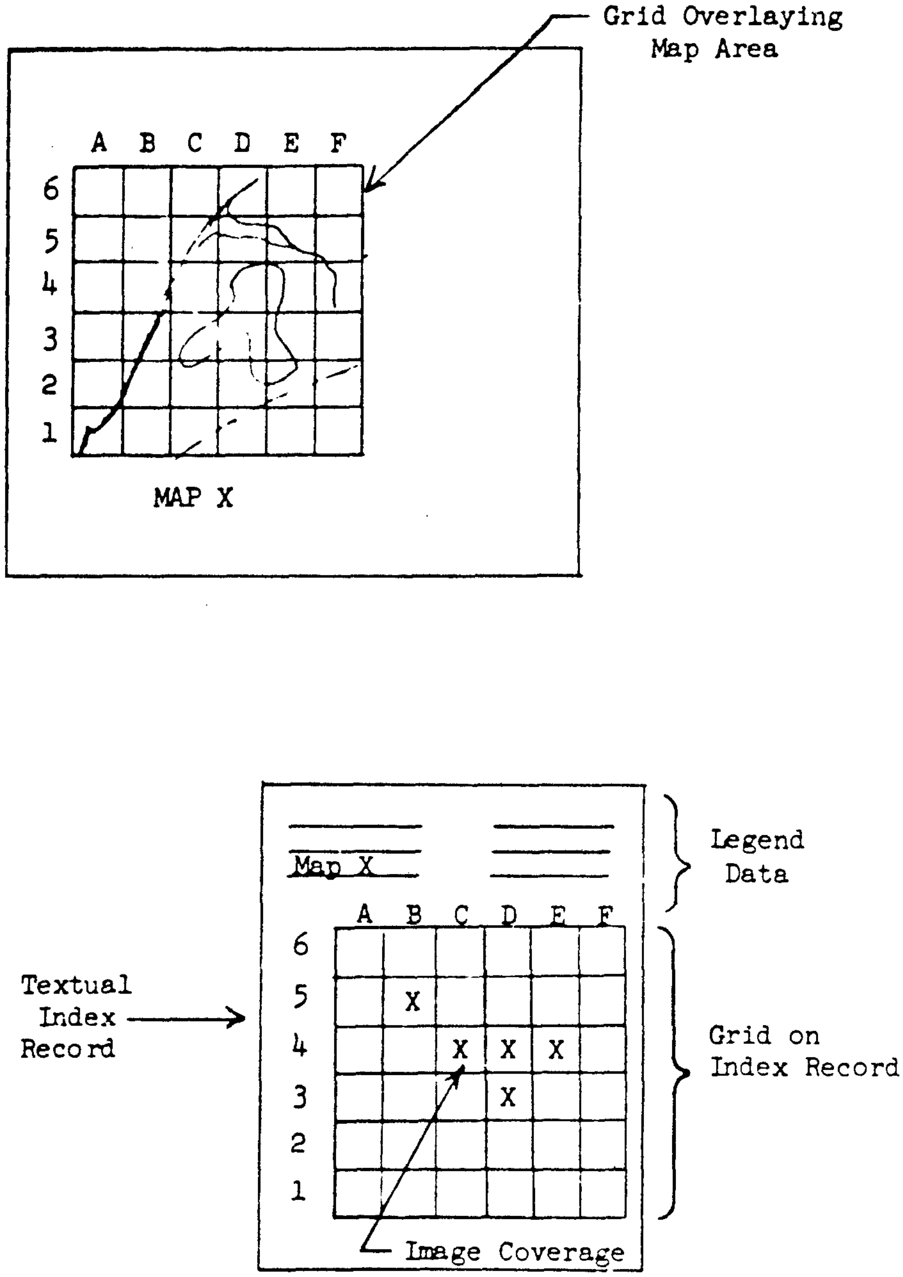

Figure 2. Example of a Map Grid and Corresponding Textual Index Record.

been prepared. The interpreter then searches through his prior coverage index to identify a mission whose coverage will enable him to answer the requirement. From the index, he obtains the accession number(s) of the desired roll(s) of imagery. Using the accession number(s), he retrieves the roll(s) of film from storage.

SPECIFIC OBJECTIVES

The major objective of the present study was to compare experimentally two indexes, one graphic and the other textual, which are used by an image interpreter to retrieve tactical imagery for specific geographical areas. Additional objectives were to investigate how a specific requirement for area coverage affects the use of indexes by an interpreter. Requirement variables included size of an area, location of an area relative to a base map, and whether or not an area lies on two adjoining maps. Finally, the study attempted to relate certain internal characteristics of the two indexes to interpreter performance.

EXPERIMENTAL METHOD

Sample

The sample comprised 16 image interpreters just finishing training at Fort Holabird (1st and 2nd lieutenants) and NCOs and enlisted men assigned to the U. S. Army Personnel Research Office or attached to the 1st Military Intelligence Battalion at Fort Bragg. Each subject worked through each indexing problem in the first experiment and then through each indexing problem in the second experiment.

Experimental Materials

Graphic Index. Thirty mission plots and their corresponding legends were prepared on transparent acetate sheets.[a] The overlays were keyed to the map of Neagumgang in Korea, Scale 1:50,000, Army Map Service (AMS) L751. Twenty mission plots were prepared on transparent acetate sheets and keyed to the map of Kosong in Korea, Scale 1:50,000, AMS L751, which adjoins the Neagumgang map. The order of missions within the index was random. Figure 1 is a typical graphic index record.

---

[a] Each mission was plotted on a separate overlay. This procedure appeared to represent a likely baseline situation. Another method was to put several missions on a single overlay and color code each mission.

Textual Index. A textual index was prepared using the same missions as for the graphic index. Details of developing the textual index format for presenting area coverage are discussed in Appendix C. Basically, the grid upon the index record represented a 6 x 6 matrix dividing a 1:50,000 AMS map into 36 equal major areas, each designated by a capital letter and a number (Figure 2). For the map grid, each of these areas was further divided into four equal areas designated by the small letters a, b, c, and d. The textual index record contained this grid, except that subareas were listed in a single row of four units instead of two rows of two units. Image coverage was indicated by an X in each appropriate grid area. Figure 3 shows a textual index record used in the experiments. Where there was overlap coverage, the index record contained the words, "See Also Map Coverage" below the primary grid, as well as a display of the overlap coverage.

In addition to the textual index itself, for Experiment 2, two special forms were prepared to assist the subjects in using the index: a transparent index record to help select relevant index records and a form for recording each selected index record's coverage (Appendix C).

Problem Areas. Eight areas were designated as problems for each experiment. In Experiment 1, four were simply points and four were small areas (areas smaller than a single grid area). In Experiment 2, all the areas were larger than a single grid area; four areas appeared on a single map and four areas encompassed two adjoining maps. Each problem area is described further in Appendix C.

Experimental Tasks

Each interpreter serving as subject was provided a textual index or a graphic index. He was then given a series of problems which involved searching the index to locate imagery coverage for designated points or areas. Each point or area was marked on an overlay attached to an 1:50,000 AMS map. The interpreter was informed that there was at least one correct solution and that he was to record the first solution he found. In Experiment 2, he was also told how many accession numbers were required for a correct solution.

For each problem, the subject first checked to be sure he understood the location of the required area or point on the map and, in the case of the textual index, he verified the alignment of the grid over the map. After being told to start, he searched the index records as rapidly as possible for an index record or records which provided a correct solution to the problem. For the graphic index, this search normally involved aligning five or six index records (overlays) simultaneously over the map and determining if any of the index area plots covered the problem area. When a solution (or partial solution) was detected, the subject then selected the correct overlay within that subset. For the textual index, the subject first determined which map grid areas were covered. He then went through the index to find an index record having

SENSOR ID: Vertical Photo

DATE: 9 May 1965

TAKING ORG: 17 TRS - 565

APPROX. SCALE: 1:5800

ACCESSION NO: 069

	A				B				C				D				E				F			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
6										X		X	X	X	X		X							
5																			X	X			X	X
4																								
3																								
2																								
1																								

SEE ALSO MAP COVERAGE (6892 I)

	A				B				C				D				E				F			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
6				X	X	X	X																	
5			X				X	X																
4																								
3																								
2																								
1																								

Figure 3. Example of a Textual Index Record.

coverage for those grids. Once he had achieved a solution, he recorded the accession number(s) on a recording form provided. If the solution was incorrect, the experimenter asked the subject to continue to search for the correct solution.

To summarize, the experimental tasks of the subjects were to:

1. Verify the area where coverage was required, and, in case of the textual index, determine what grid areas the problem area covered.

2. Search through the index records until a record (or set of records) was found that satisfied the problem requirement.

3. Record the accession number of the selected index record(s) on the appropriate form.

Experimental Variables

The primary independent variable in the study was the method of indexing tactical imagery. The two indexing methods, designated graphic (G) and textual (T), have been briefly described. The methods were compared under a variety of conditions. An analysis of situations that might be encountered using an area-oriented imagery index indicated that the following conditions should be manipulated or controlled in comparing the two methods:

1. Location of problem area. The location of the problem area on a map might be important, particularly as some locations might have more or less photo coverage than other locations.

2. Size of problem area. The search for coverage for a point (i.e., a single target) might be different than for a large area.

3. Problem area overlap. The base map covered an area which appeared likely to include the primary area of interest of a IIF. However, if primary concern was a location at or near the boundary of the map area, a problem area requirement might involve searching more than one map. This factor appeared important since, in the case of a problem area covering two maps, the search task had to include index records keyed to both map areas.

4. Amount and type of image coverage available. Obviously, the size (number of index records) and content of the index itself is an important variable which affects the interpreter's performance in searching an index. For example, the larger the index or the smaller the scale of the imagery, the more likely the user of the index is to find a solution to a problem.

The only dependent variable used was time in seconds to achieve a correct solution. (Preliminary trials indicated that too few errors would be made in the search task to warrant statistical treatment. A record was kept of the errors, however.) Time scores which are obtained without a cut-off limit are typically skewed; i.e., there are a few scores that are extremely large which tend to distort the means. This was found to be true in the indexing study. Therefore, prior to analysis, a set of logarithmic scores [3] was obtained from the raw scores.

Experimental Design

Because of differences in the basic search task between small-area and large-area problems, especially in the case of the textual index, it was decided to conduct two separate experiments. However, the design and statistical plans for Experiments 1 and 2 were identical. In Experiment 1, the two indexes were compared using problems with small areas or point locations for which image coverage was desired, while in Experiment 2 the methods were compared using problems with large areas some of which covered two maps.

A Latin Square design, shown in Figure 4, was used in both experiments. The basic design was replicated using two sets of 8 subjects in each experiment. The second set of subjects (9 through 16) followed the same sequences as subjects 1 through 8. There were two groups within each set of 8 subjects. The first group took the graphic index first, while the second group took the textual index first.

Data Collection Procedures

The experimental data were collected in the U. S. APRO surveillance systems laboratories, at Fort Holabird, and at Fort Bragg. The subjects were tested individually by the experimenter. Each subject went through the entire test period at one sitting (about three hours). Each experimental session was organized as follows:

General Explanation of Test

Experiment 1

Specific instructions for first indexing method

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[3] The logarithmic scores were calculated by the formula:

$$[\ (\mathrm{Log}_{10}\ x) - 1\ ] \times 100 = \bar{\underline{x}}$$

One was subtracted from the log score and the result was then multiplied by 100 in order to obtain numbers which could be easily manipulated in the analyses. Raw scores are shown in Appendix A.

		Method of Indexing							
	Subject	Graphic Index (G)				Textual Index (T)			
Group 1	S_1	1	2	3	4	5	6	7	8
	S_2	2	4	1	3	6	8	5	7
	S_3	8	7	6	5	4	3	2	1
	S_4	6	8	5	7	2	4	1	3

		T				G			
Group 2	S_5	5	6	7	8	1	2	3	4
	S_6	7	5	8	6	3	1	4	2
	S_7	4	3	2	1	8	7	6	5
	S_8	3	1	4	2	7	5	8	6

Trials	I	II	III	IV	V	VI	VII	VIII

Note:

Problems 3, 4, 6, and 8 are Point (P) problems and 1, 2, 5 and 7 are Small area(S) problems in Experiment 1.

Problems 1, 3, 5, and 7 are No overlap (N) problems and 2, 4, 6, and 8 are Overlap (O) problems in Experiment 2.

In Group 1 above, a block of graphic conditions occurred before a block of textual conditions.

In Group 2 above, a block of textual conditions occurred before a block of graphic conditions.

The above design was replicated for Subjects 9-16.

Figure 4. Latin Square Experimental Design for Indexing Experiments.

Training on above

Testing on above

Repeat for other indexing method

Experiment 2

Specific instructions for first indexing method

Training on above

Testing on above

Repeat for other indexing method

A data collection form was provided each subject on which to record accession numbers (Figure C-7). The experimenter had a form for recording data about each subject and the time taken to solve each problem. The experimenter measured time using a stop watch and recorded any errors made by the subject (Figure C-8). Time was measured in both experiments from the moment a subject received the map with the problem area on it until he recorded the correct accession number(s). Once any solution was obtained, the watch was stopped. If the solution was incorrect, the subject was informed and the stop watch restarted.

RESULTS

The analysis of variance solutions for the log time scores of Experiments 1 and 2 are shown in Tables 1 and 2.[1] In both experiments, significant variance ratios were obtained for both the method of indexing and the problems within area and problems within overlap.

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[1] The e_1 term in Tables 1 and 2 was used to test all within subject factors except the area factor in Experiment 1 and the overlap factor in Experiment 2. In these two cases, e_2 was thought to be the more appropriate error term since these factors are random factors, i.e., they sample only the range of the overlap or area dimensions. The e_3 term in the between subjects part of the analyses was used to test sequences within groups factor which, when found not significant, was designated e_4 and used to test the final between subjects factor.

Table 1

EXPERIMENT 1: ANALYSIS OF VARIANCE OF LOG TIME SCORES

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
<u>Between Subjects</u>				
Sequences				
Groups	1	147	147.00	0.27
Sequences w/Groups (e_4)	6	3,167	527.83	2.77
Subjects w/Sequences (e_3)	8	1,524	190.50	
<u>Within Subjects</u>				
Trials				
Blocks of Trials	1	193	193.00	0.43
Trials w/Blocks	6	3,956	659.33	1.48
Problems				
Point versus Area Factor	1	6,258	6258.00	2.45
Problems w/Area (e_2)	6	15,336	2556.00	5.74*
Method of Indexing	1	4,313	4313.00	9.69*
Latin Square Error plus Subjects w/Sequences x Trials (e_1)	97	43,155	444.90	
TOTAL	127			

*F ratio significant, P < .01

Table 2

EXPERIMENT 2: ANALYSIS OF VARIANCE OF LOG TIME SCORES

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
<u>Between Subjects</u>				
Sequences				
Groups	1	18	18	0.01
Sequences w/Groups (e_4)	6	8,774	1,462	4.24
Subjects w/Sequences (e_3)	8	2,757	345	
<u>Within Subjects</u>				
Trials				
Blocks of Trials	1	2	2	0.00
Trials w/Blocks	6	4,113	686	1.30
Problems				
Overlap Factor	1	2,775	2,775	1.10
Problems w/Overlap (e_2)	6	15,117	2,520	4.79*
Method of Indexing	1	34,126	34,126	64.88*
Latin Square Error plus Subjects w/Sequences x Trials (e_1)[a]	97	51,048	526	
TOTAL	127			

*F ratio significant, $P < .01$

[a] The Latin Square error was significant ($F = 4.37$) when the term used to test the error term was subjects w/sequences x trials. From an informal analysis of the error term, this result was considered due to an interaction between problems and method of indexing caused by the deviation of Problem 3 from the general trend (See Table 4). However, when using the pooled error term as in Experiment 1, the F's for method of indexing were very significant and appeared significant for the problems within overlap factor. Since these results agree with Experim[illegible] and because of the magnitude of the F's, the differences were tr[illegible] significant though caution is warranted because of the invalid error term.

Method of Indexing

Tables 3 and 4 present the log time means for the two indexing methods for each problem in both experiments. Although these means are significantly different, the direction of the difference is not the same in the two experiments. In Experiment 1, the textual means for the problems are smaller than the graphic means while in Experiment 2, the graphic means are smaller than the textual means. This result may be explained as follows: With the textual index in Experiment 1, the subject had merely to remember a simple designator, composed of three characters--(e.g., F4b) --or four, if the problem fell across two subarea boundaries (e.g., F4b and c). Keeping these designators in mind, a subject could quickly scan the textual index records and select an appropriate record. An exception was Problem 7. This problem required the subject to remember two different grid designators, D4b and D3d, since the problem area fell along the border of two major grid areas. Thus, Problem 7 is similar to the large area problems in Experiment 2 in the complexity of the textual grid requirements.

In the case of the graphic index, the manipulation of the large heavy overlays by the subjects was sufficiently cumbersome to cause the time scores to rise above those of the same problems using the textual index as indicated by the mean scores in Experiment 1. However, once the textual index became sufficiently complex that a subject could not remember the grid requirements and had to use the transparent index record and the recording forms to utilize the index as in Experiment 2, the time scores for the textual index increased above those for graphic index. In Experiment 2, note that Problem 3 reverses sharply the general trend for the textual index. Problem 3 approached the simplicity of problems in Experiment 1 in that it required but one major grid area designator even though it covered all that grid; i.e., the subject had only to look for "all of F6," rather than "F6a, F6b, F6c, and F6d."

The matter of precision also contributed to the differences between the two methods, especially in Experiment 1 where the problem areas were smaller than the grid areas. Using the textual index, the subject was to locate mission coverage for all the grid areas that were partially or completely covered by the problem areas. For Experiment 1, a solution could be obtained for a problem area even though the mission selected did not cover the problem area if the mission covered the grid sufficiently (25% or more) to cause the grid to be marked with an X. This precision would not be as critical in Experiment 2, as the problem areas were large compared to the grid areas and the problem areas usually covered good portions of all the grid areas affected. The choice of grid size for a textual index is important and should be studied further. If precision is required, then a graphic index may be superior to a textual index unless the latter has a grid whose elements are considerably smaller than the problem areas likely to be encountered when using it.

Table 3

EXPERIMENT 1: LOG TIME MEANS FOR GRAPHIC AND TEXTUAL INDEXES

Problem Number	Problem Type	Graphic	Textual	Total
1	Sm. Area	51.0	49.8	50.4
2	Sm. Area	56.9	30.5	43.7
3	Point	58.0	27.9	42.9
4	Point	50.9	32.2	41.6
5	Sm. Area	57.4	58.9	58.1
6	Point	62.8	44.5	53.6
7	Sm. Area	72.6	91.8	82.2
8	Point	49.8	30.9	40.3
TOTAL		57.4	45.8	

Table 4

EXPERIMENT 2: LOG TIME MEANS FOR GRAPHIC AND TEXTUAL INDEXES

Problem Number	Problem Type	Graphic	Textual	Total
1	No Overlap	90.6	158.6	124.6
2	Overlap	109.4	162.1	135.8
3	No Overlap	130.8	96.0	113.4
4	Overlap	121.2	133.8	127.5
5	No Overlap	111.0	171.9	141.4
6	Overlap	109.6	129.0	119.3
7	No Overlap	83.1	137.8	110.4
8	Overlap	130.6	158.5	144.6
TOTAL		110.8	143.5	

Areas on Which Problems were Based

The analysis for both experiments indicated that problem areas were significantly different among themselves. However, the point versus area factor in Experiment 1, and the overlap factor in Experiment 2, did not produce these differences (See Tables 1 and 2). Although the problem areas in the two experiments varied in size, overlap, and in location on the base map, the factor that probably contributed most to the differences among problems was the content of the indexes. In the case of the graphic index, a problem area sometimes lay directly under the path of a flight line containing small scale photo coverage and could be quickly detected. In other cases, the scale of the coverage was larger, and therefore the index record was more difficult to recognize as being a solution. In some cases, it was obvious that only two or three index records could possibly contribute to a solution, while in other cases a large proportion of the index records covered the general area, and the subjects had to go through a large number before finding the one he wanted.

Another factor contributing to the differences among problem areas in Experiment 2 was the large variation in the number of grids to be covered, which resulted in corresponding difficulty in using the index record and recording forms. Finally, depending upon the coverage pattern on a textual index record in Experiment 2, the required areas might be detected either easily or with difficulty. If the general area was completely covered with X's or if only the required areas were covered with X's, it was fairly simple for the subject to detect a solution. If the general area contained many blanks and X's which alternated with each other forming a checkered-like pattern, it was more difficult to detect a solution, even in Experiment 2 when a transparent template was used to help simplify this situation.

Other Variables

The means for trials, groups, and sequences are presented in Table 5. In both experiments, there were no significant differences among trial means, indicating no practice effect during the experimental sessions. (The subjects had received considerable training prior to testing.) There were no differences in groups associated with the sequence of textual and graphic methods.

Error Scores

Relatively few errors were made by the experimental subjects in accomplishing the problems. In all, the 16 subjects produced 256 scores in the two experiments. Errors occurred in only 19 instances, broken down as follows:

	Graphic	Textual
Experiment 1	1	3
Experiment 2	5	10

There were more than twice as many errors with the textual index as with the graphic index. There were more than twice as many errors in Experiment 2 as in Experiment 1. These data support the time score results which showed that the tasks in Experiment 2 were the more difficult and that the subjects used the graphic index more readily for large area problems.

Table 5

LOG TIME MEANS FOR TRIALS, SEQUENCES, AND GROUPS

Experiment 1				Experiment 2			
Trial Means	Sequence Means		Group Means	Trial Means	Sequence Means		Group Means
I 58.8	1	56.6	1 52.7	I 123.6	1	144.2	1 126.8
II 41.8	2	53.3	2 50.7	II 124.8	2	119.4	2 127.5
III 56.4	3	51.5		III 129.6	3	126.4	
IV 44.5	4	49.3		IV 131.1	4	116.9	
V 55.8	5	60.2		V 129.1	5	126.1	
VI 48.6	6	51.2		VI 115.4	6	134.8	
VII 51.8	7	48.5		VII 135.9	7	127.6	
VIII 55.1	8	42.1		VIII 127.5	8	121.5	

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based on the results presented in the preceding section:

1. In general, the type of requirement or request that will be imposed upon an index--the kinds of questions that are likely to be asked of an index--is important in the choice of a manual indexing method for a tactical image processing system.

2. A graphic index for depicting tactical imagery stored on roll film is superior to a textual index if the areas or targets for which coverage is required are large or if precision is required when selecting imagery coverage.

3. A textual index for depicting tactical imagery stored on roll film is superior to a graphic index if the areas for which coverage is desired are small or if the image coverage does not have to be precisely defined.

The following recommendations are made with regard to future efforts in this area:

1. The textual index concept should be further investigated for use in a computerized TIIF where a variety of index listings can easily be provided. In particular, studies should be made of the fineness of the grid which is used to quantify the area, the format of the portion of the index record which depicts area coverage, and the development of computerized or other aids to relieve the interpreter of any bookkeeping tasks associated with using a textual index.

2. The graphic index record format should be studied with a view to improving the pictorial representation of the area covered, evaluating the effect of displaying several missions on a single overlay, and simplifying the task of searching the index records.

3. A combination of graphic and textual indexing methods should be considered. A textual index might be useful as a filter or screening technique for selecting a subset of graphic index records which could then be searched to obtain precise coverage over a specified area. Besides providing manual back-up materials in case of equipment malfunction, the combination approach in a computerized TIIF would allow selection of previous missions on source data (date, sensor) as well as area coverage. The TIIF computer could perform the search of the textual index.

APPENDIXES

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APPENDIX A
RAW SCORES OBTAINED IN INDEXING EXPERIMENTS

Table A-1

TIME SCORES IN SECONDS FOR EXPERIMENT 1

	Subject								
		G				T			
roup 1	S_1	24	38	52	48	39	33	107	18
	S_2	59	35	25	28	43	16	22	76
	S_3	24	44	23	36	35	36	21	142
	S_4	43	25	62	47	50	28	42	19
		T				G			
oup 2	S_5	55	33	93	32	37	29	37	28
	S_6	130	43	37	19	32	18	34	25
	S_7	25	09	13	38	44	69	48	53
	S_8	06	14	20	30	123	57	27	20
		G				T			
up	S_9	52	21	27	35	57	38	40	22
	S_{10}	61	23	54	40	21	17	31	51
	S_{11}	64	53	69	16	08	32	14	40
	S_{12}	57	27	33	32	16	12	22	32
		T				G			
ıp	S_{13}	37	30	190	19	34	63	32	25
	S_{14}	58	39	12	17	58	31	37	27
	S_{15}	29	20	30	29	25	36	42	36
	S_{16}	22	12	28	10	60	30	31	68
rials		I	II	III	IV	V	VI	VII	VIII

Table A-2

TIME SCORES IN SECONDS FOR EXPERIMENT 2

	Subject								
		G				T			
Group 1	S_1	242	151	272	258	1173	375	257	647
	S_2	44	105	38	164	156	473	552	244
	S_3	252	89	113	159	143	175	523	451
	S_4	136	179	96	62	312	233	470	113
		T				G			
Group 2	S_5	471	199	242	322	92	83	150	163
	S_6	414	734	520	174	374	57	172	128
	S_7	183	80	899	444	510	89	99	152
	S_8	80	380	345	537	58	100	306	104
		G				T			
Group 1	S_9	250	198	233	254	365	120	244	208
	S_{10}	92	155	39	127	174	370	406	252
	S_{11}	202	63	261	100	209	92	497	224
	S_{12}	128	118	112	51	262	185	263	86
		T				G			
Group 2	S_{13}	409	259	167	328	51	175	124	176
	S_{14}	163	413	361	194	324	74	96	253
	S_{15}	215	71	277	491	150	78	117	231
	S_{16}	71	483	284	335	63	130	109	93
Trials		I	II	III	IV	V	VI	VII	VIII

APPENDIX B

ORIENTATION OF SUBJECTS IN INDEXING EXPERIMENTS

INSTRUCTIONS TO SUBJECTS:

"The test that you are about to take is to help evaluate two ways of indexing tactical imagery cover stored on roll film. One method is called a graphic method and is similar to existing methods used by the military services where photo coverage is plotted on overlays which are keyed to a base map [Experimenter shows the subject a graphic index record and a map]. The other method is a textual index where geographic areas are described in terms of coded quadrants which represent areas of image coverage [Experimenter shows subject a textual index record]. These coded areas are also keyed to a base map. Each index record, in both types of indexes, represents a single mission on a single roll of film. The scale of the imagery varies from about 1:2500 to 1:7500 and is all vertical photography. The photo coverage for the graphic method is directly depicted on an overlay by means of area plots every fifth frame and for the textual method is represented by check marks (X's) in cells of the index records. [Experimenter shows subjects similar textual and graphic index records]. When the photo coverage covers more than a single map area, you will find a dotted line on the graphic index record indicating that there is an overlay keyed to an adjoining map with the remaining coverage, or there will be a "See Also Map Coverage' indication at the bottom of the textual index record. You will need to use this information when your problem involves finding coverage for two map areas."

"The test is divided into two major phases; the first test phase compares the two types of indexes using small areas and points on a single map [Experimenter points to map of Naegumgang] and the second test compares the indexes using large areas and on occasion two maps [Experimenter points to both the Naegumgang map and the Kosong map]. In the first test, you will be given training on four problems using one of the index methods. Some of you will start with the graphic index, while others will start with the textual index. Once you have worked the four training problems and have demonstrated that you understand the procedure, you will be given four test problems, one at a time, using that same type of index. I will tell you to start using the index by saying "Start." At this time, I will start a stopwatch and you will begin to search through the index. Once you have recorded your answer (accession number) on the recording sheet, I will stop the watch and check your solution against the answer list. If you are correct, I will indicate this, and we will proceed to the next problem. If you are incorrect, I will tell you this, and you will continue to work at the same problem until you obtain another solution. I will restart the stopwatch when you restart working the problem. This procedure will continue until you obtain a correct solution to the problem."

"Once the four test problems are completed, you will be trained on the same four training problems using the other indexing method. Again, after completing the training problems, you will be given four more new test problems using the second indexing method. Are there any questions? [Experimenter answers questions.] We will now start the first test phase."

The following instructions were given subsequent to the completion of Experiment 1.

"We are now ready to begin the second part of the testing. As before, you will be given eight problems, four involving each type of index. Prior to the testing on each type of index, you will work two training problems. You will use the index in the same order as you did before. The major difference between what you will do now and what you did before is that you will be using problems that are larger in area, occupy more than one map area in some cases, and require two or three accession numbers for a solution."

Instructions for the Graphic Index in Experiment 2.

"The graphic index for this test involves two sets of overlays--one geared to the base map, Naegumgang, which you used before, and one set geared to the adjoining map, Kosong. Flights or missions that include both maps have dotted lines at the border of the overlay and have identical accession numbers. If the problem involves a single map, you will operate pretty much as you did before. The only difference is that more than one overlay will be required in order to completely cover an area. Since it is the right combination of overlays that is important, you will be told whether you will need two or three accession numbers for a solution. You need to keep track of those index records which contribute some coverage until you get the complete solution. This can be done by leaving these overlays on the map or in a special place close to you. As soon as you obtain a complete solution with the correct number of accession numbers, record the solution on the recording form."

"For problems involving two map areas, a good procedure is to solve the problem for the prime map area (Naegumgang) first. Then, if any of the index records have dotted lines indicating overlap coverage, go to those same accession numbers in the index records for the adjacent map to see if those records solve the area requirement there also. Usually, these records will provide at least some of the required coverage. Then you can proceed to obtain the rest of the solution. Again, you will be told how many accession numbers will be required for the solution. Also remember that index records having coverage in adjoining map areas have only one accession number. Are there any questions? [Experimenter answers questions.] Now we will work the two training problems."

Instructions for the Textual Index in Experiment 2.

"The textual index for this test involves a set of records for each of the two maps. However, any coverage that falls into an adjoining map areas is included in the cross-reference section at the bottom of a record. The index records for the primary map, Naegumgang, include the 30 missions over that map area as well as 15 missions that are continued into the adjacent map area of Kosong. Consequently, the primary set of textual index records contains information on 45 of the 50 area plots. As you might expect, most problems can be completely solved using just the primary index set. However, if you do need coverage unique to the adjoining map area, you can check those index records."

"Because it is difficult to remember all of the grid areas that are required to solve these more difficult problems, two items have been provided to assist you in searching the records and determining the correct accession numbers. The first of these items permits you to record all the grid areas for which you want to get image coverage. [Experimenter shows the textual index record accession number recording form illustrated in Figure C-3.] The primary grid characters (e.g., A3) are written in the top row, and the subarea characters (e.g., b) are written in the second row. Now, as you go through the index, for each index record that has coverage you record an X in the appropriate column or columns and the corresponding accession number at the left. You continue in this fashion until you have coverage for all the grid areas indicated at the top using the correct number of accession numbers, either 2 or 3. Once you have the solution, you record the accession numbers of the solution index records on the answer form."

"In addition, there is another form that will be helpful to you. This is a transparent acetate template which contains a blank index record form upon it. [Experimenter shows this item to the subject.] After you have recorded the grid areas you must search for, you should, using this grease pencil, indicate these areas on the template. You can do this by outlining each of the boxes or putting an X in each box. Now, when you think an index record may have coverage for your problem, you place this template over the index record sheet and determine what grid areas are covered. This simplifies having to study each index record. Are there any questions? [Experimenter answers the questions.] All right, now we will work the two training problems using the textual index and these aids."

APPENDIX C

DEVELOPMENT OF EXPERIMENTAL MATERIALS AND RECORDING FORMS

GRAPHIC INDEX

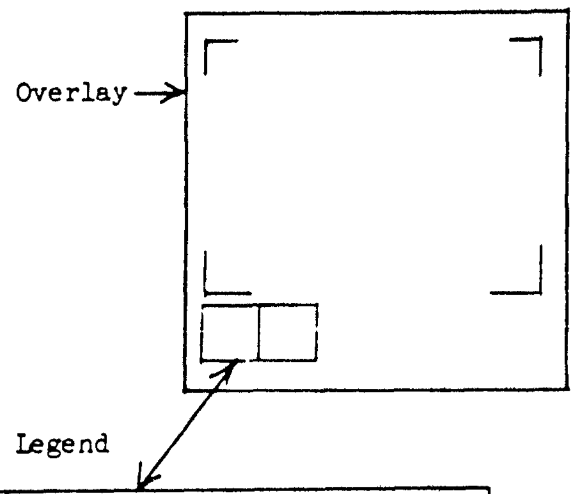
The graphic index consisted of a series of transparent overlays which depicted the boundries of the coverage of the imagery. (See Figure 1 in text). Each mission was plotted on a separate overlay and each overlay was keyed to a base 1:50,000 AMS map. Each overlay (area plot and legend) was an index record, and a set of overlays representing all the missions was the graphic index. The legend on each overlay contained source data about the mission such as the name of the image-taking organization, the date of the mission, and the approximate scale. Figure C-1 shows a legend containing source data based on one of the overlays. However, only the accession number and the reference to the base map were used in the experiment.

Since a single photo mission may cover more than one base map, many of the records had dashed lines at the border indicating that there was additional coverage in an adjoining map area (Figure 1). A separate overlay containing the coverage keyed to the adjoining map had the same accession number, since it represented the same mission.

Thirty index records were developed for the map Naegumgang of Korea, Scale 1:50,000, Army Map Series (AMS) L751, Sheet 6829 IV and twenty index records for the map Kosong of Korea, Scale 1:50,000, AMS L751, Sheet 6829I; the latter map area adjoins the former map area along the former's eastern boundary. These particular maps were chosen because several copies were available to the experimenter. The Naegumgang map was designated as the primary area of interest for the experiments. Fifteen of the thirty index records for Naegumgang contained missions that overlapped the Kosong map. Thus, the Kosong index contained 15 overlap missions and five unique to the Kosong area. The scale of the image coverage varied from approximately 1:2500 to 1:7500. The scale of each mission was indicated in the legend of that record. To provide realistic mission plots, the mission plots in the Standard Indexing System library at Aeronautical Charting and Information Center in Arlington, Virginia were examined. Several of the index records developed for the experiments contained mission plots similar to plots of missions actually flown by reconnaissance aircraft.

The area plot on each overlay consisted of a series of individual plots of discrete frames of imagery linked by a straight line. The size of the individual frame was inversely related to the scale: the larger the scale, the smaller the individual plot. The line connecting the individual plots indicated the flight line of the aircraft. The imagery frames were plotted about every fifth frame or every time the flight line changed direction. Therefore, the actual coverage fell within two

Graphic Index Record



SENSOR ID	Vert Photo	AREA	Korea, 1:50,000
DATE	9 May 1965	AMS	L751
TAKING ORG	17 TRS - 565	SHEET	6829 I
APPROX. SCALE	1:5800	ACCESSION NO.	069

Figure C-1. Legend for a Graphic Index Record

parallel lines that bounded the plotted frames. The overlays were transparent sheets of acetate whose dimensions were 18-1/2 by 20 inches. The plotting area itself was the same size as the AMS map base--14-1/2 by 17 inches. The corner alignment marks on the overlay indicated where the overlay was to be aligned with the map. The index records for each map area were stored separately and were unbound.

TEXTUAL INDEX.

The textual index records were developed using the area coverage of the graphic index records. Some of these textual records were subsequently modified in order to equalize the number of index records required for a solution to a specific problem.

The grid selected for the textual index was a 6 x 6 matrix which divided the base map area into 36 equal areas whose locations were identified as shown in Figure C-2. Each area was further subdivided into four equal areas, lettered a through d, proceeding as before from left to right and from bottom to top. Thus, each 1/144 of a map area was designated by three characters (e.g., B3c). This grid was felt to be sufficiently precise to provide a test of validity of the indexing concept.

The grid was placed over each of the graphic overlays to determine what grid areas were covered by each mission. In this manner, for each overlay, a textual index record was generated. For a grid area to have coverage, at least 25% of the grid had to be covered by a graphic plot. Obviously, a change in the criterion would change the content of the index record--the higher the percentage figure used as the criterion, the less likely a grid would be selected. Figure 3 in the text of the report depicts a typical textual index record used in the experiment. The index records were printed on standard size government bond paper.

In order to depict overlap of areas into an adjoining map, a cross-referencing scheme was utilized. Whenever a mission included coverage in an adjoining map, a "See Also" reference to the appropriate map base was inserted with a print-out of the coverage of that map. Because of the cross-referencing feature, the textual index could contain more information about photo missions in a smaller set of index records than the graphic index. This cross-referencing was included because it is a logical characteristic of a textual indexing system.

As in the case of the graphic index, there were 30 index records for the primary map area (Naegumgang) of which 15 contained the cross-reference information. The secondary map area (Kosong) included 20 index records of which 15 were cross-referenced back to the primary map area.

With the textual index, the subject utilized the grid which was keyed to the problem map. When working a problem, the subject first

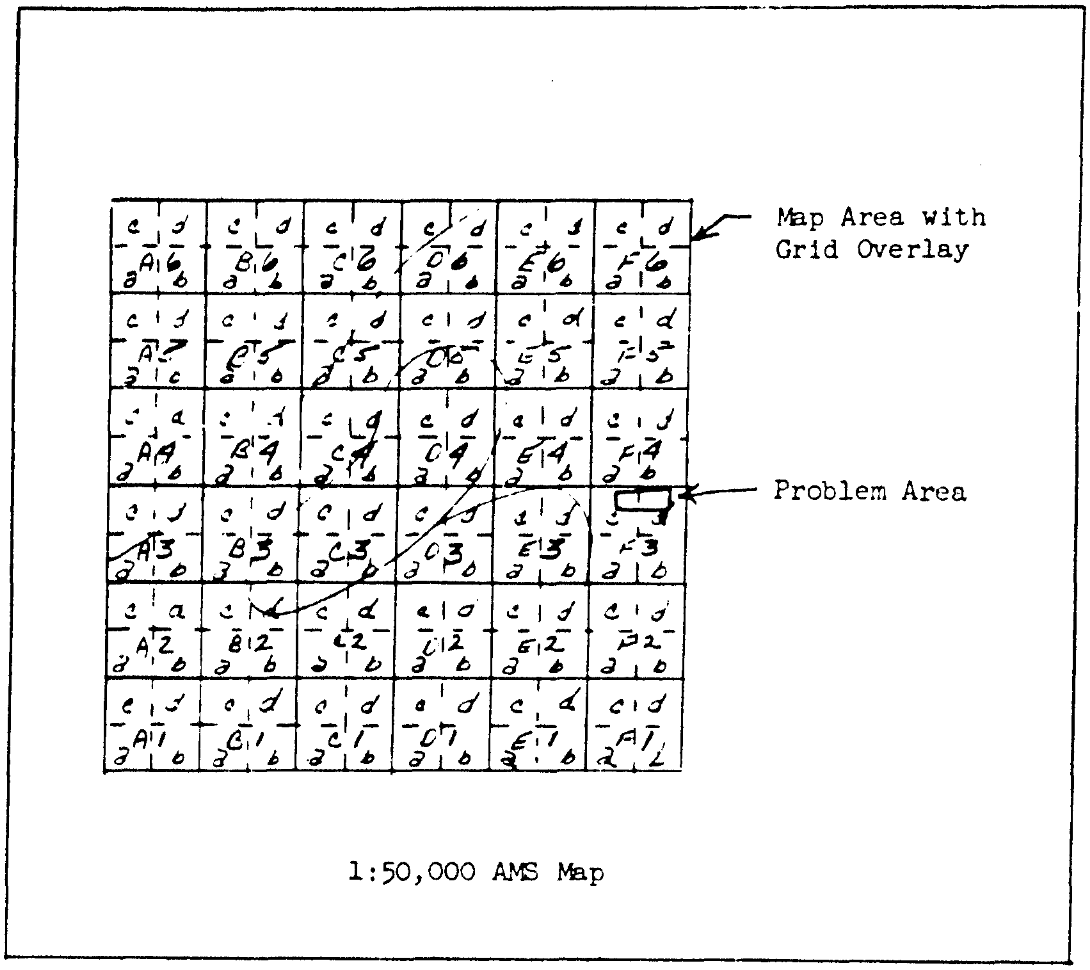


Figure C-2. Grid Used to Generate Textual Index and Sample Problem.

determined what grid areas required coverage. In the case of the problem area in Figure C-2, areas F3c and F3d require coverage. The subject would then search through the primary index until he located the index records that provided complete coverage for F3c and F3d. Since some of the problems were quite large, it became difficult to remember all the required areas as well as to keep track of all the index records which contributed some coverage toward the solution. For example, eight or nine index records might provide some coverage for a problem requiring six small grid areas for a solution. Of these, two or three might do the complete job, but the right combination might not become known to the searcher until most of these records had been identified as partial contributors. It was decided to divide the indexing experiment into two phases, one using as problem sources small areas and points occupying a single map area, (Experiment 1) and one using large areas, some of which were covered by more than one map area (Experiment 2). The latter problems included those which required several grid areas for solution.

For using the textual index in Experiment 2, a special bookkeeping procedure and two special forms were developed. A recording form was developed for listing the grid areas for each problem (Figure C-3). The prime area designators (F1, A3, etc.) were listed in the top row while the minor area designators (a, c, etc.) were listed in the second row. As the index records were searched, for each record that had one or more hits (covered one or more grid areas) the accession number was recorded and an X placed in all appropriate columns. Given a required number of records for a solution (1, 2, or more), the subject could reach a solution by determining if all the grid areas were covered by an X using the correct number of index records. Figure C-4 illustrates a solution for a problem requiring 2 index records, and occupying two map areas. When the problem occupied more than a single map base, the grid requirements were indicated on the same recording form but were separated by a heavy vertical line. In Figure C-4, this line separates F4d and A4a.

To simplify the task of comparing all the grid areas required with each index record, a transparent index record overlay was developed. It is basically a blank textual index record (Figure C-3) printed on transparent acetate. The subject, using a grease pencil, indicated each of the grid areas requiring coverage by encircling the appropriate box or putting an X in it. If, as he went through an index record, he suspected there were one or more grid areas of interest upon it, he placed the overlay over the record and quickly determined if the index record provided any coverage.

EXPERIMENTAL PROBLEM AREAS.

Eight problems were developed for each experiment.

Experiment 1. Problems 1 through 8 were points (two intersecting lines) or small areas marked in heavy black ink on a transparent acetate overlay attached to the prime map area, Naegumgang. Figure C-5 shows the approximate location and size of each of the 8 problems. For

AREA CODES

ACC. NO.										

Figure C-3 Recording Form for Textual Index

Primary Area — Secondary Area

AREA CODES

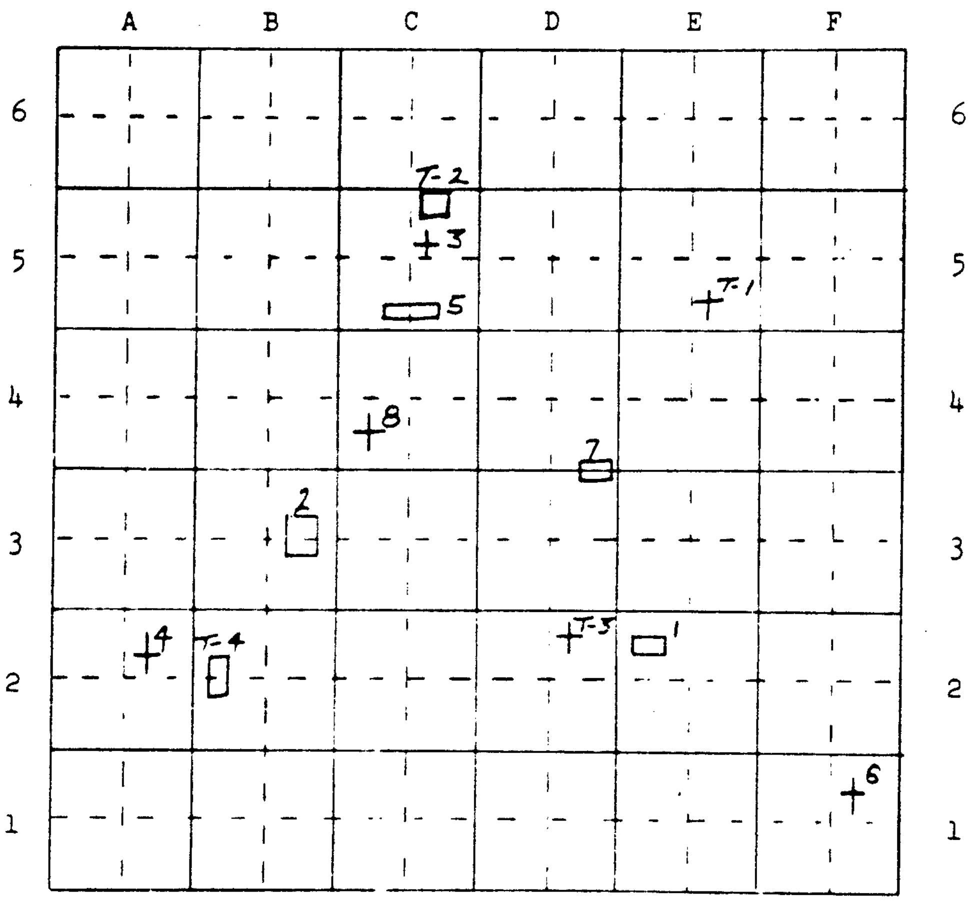
	F4				A4					
ACC. NO.	a	b	c	d	a	b	c	d		
[illegible]			X							
[illegible]					X		X	X		
[illegible]	X									
[illegible]					X					
[illegible]	X	X	X		X	X				
[illegible]	X				X	X				
[illegible]	X									
	X	X			X					
[illegible]							X	X		
[illegible]	X	X	X				X	X		
[illegible]						X	X	X		
[illegible]			X	X			X	X		

Figure C-4 Recording Form for Textual Index Completed for Problem 4

testing, each problem was on an overlay attached to a separate map. Problems 1, 2, 5, and 7 were small areas (smaller than the smallest grid area in size), while problems 3, 4, 6, and 8 were point locations. To provide for training of the subjects, four additional problems were prepared; these problems included 2 small area problems and 2 point problems. In Figure C-5, these training problems are designated T-1, T-2, T-3, and T-4. The training problems were for familiarizing subjects with both types of index.

For the graphic index, the problems were presented to the subject without a grid. For the textual problems, the transparent grid overlay was oriented correctly to the map area.

All problems in Experiment 1 required a single accession number for solution; however, some problems had more than one solution. This was equated for each problem between the indexes. Thus Problems 1, 3, 4, 5, 6, and 7 had one solution when using either index, while Problems 2 and 8 had two solutions when using either index.



Naegungang

Primary Map Area

Figure C-5. Problems for Experiment 1 (Grid over map area)

Experiment 2. A set of eight problem areas was developed, each greater in size than a single grid area. Four problems (2, 4, 6, and 8) were located so as to fall into both the primary map area (Naegumgang) and the secondary map area (Kosong). As in Experiment 1, each problem area was outlined in heavy black ink on a transparent acetate overlay on one or two maps. Figure C-6 shows the approximate location and boundaries of each of these problems. In addition, two training problems were prepared (T-1 and T-2 in Figure C-6). As in Experiment 1, these training problems were used for training on both index methods. In Experiment 2, in order to equate the difficulty of a problem for each type of index, the textual records were adjusted so that for a given problem, say Problem 4, the same number of graphic and textual records was required for obtaining a solution. There was but one unique solution for each problem. Two accession numbers were necessary for problems 1, 2, 4, 5, 6, and 7 and three accession numbers for problems 3 and 8.

SUBJECT AND EXPERIMENTER RECORDING FORMS.

For each experiment, the subject was given a copy of a special form for recording the accession number (or numbers) to each problem (see Figure C-7). As he solved each problem, he would fill in the accession number(s).

The experimenter used the form shown in Figure C-8 to record the time in seconds required for correctly solving each problem and to record other data--name of subject, date, any errors, etc. The experimenter recorded the obtained accession number to the right of the time data when more than one solution was possible.

ANSWER LISTS.

A master scoring sheet was prepared which listed all the correct solutions for each training and testing problem for both the graphic and textual index methods. In addition, for the textual index solutions in Experiment 2, a list of all index record accession numbers that contributed to a solution were listed in numerical sequence under all the required grid areas. This latter list enabled the experimenter to monitor each subject's progress in using the textual index.

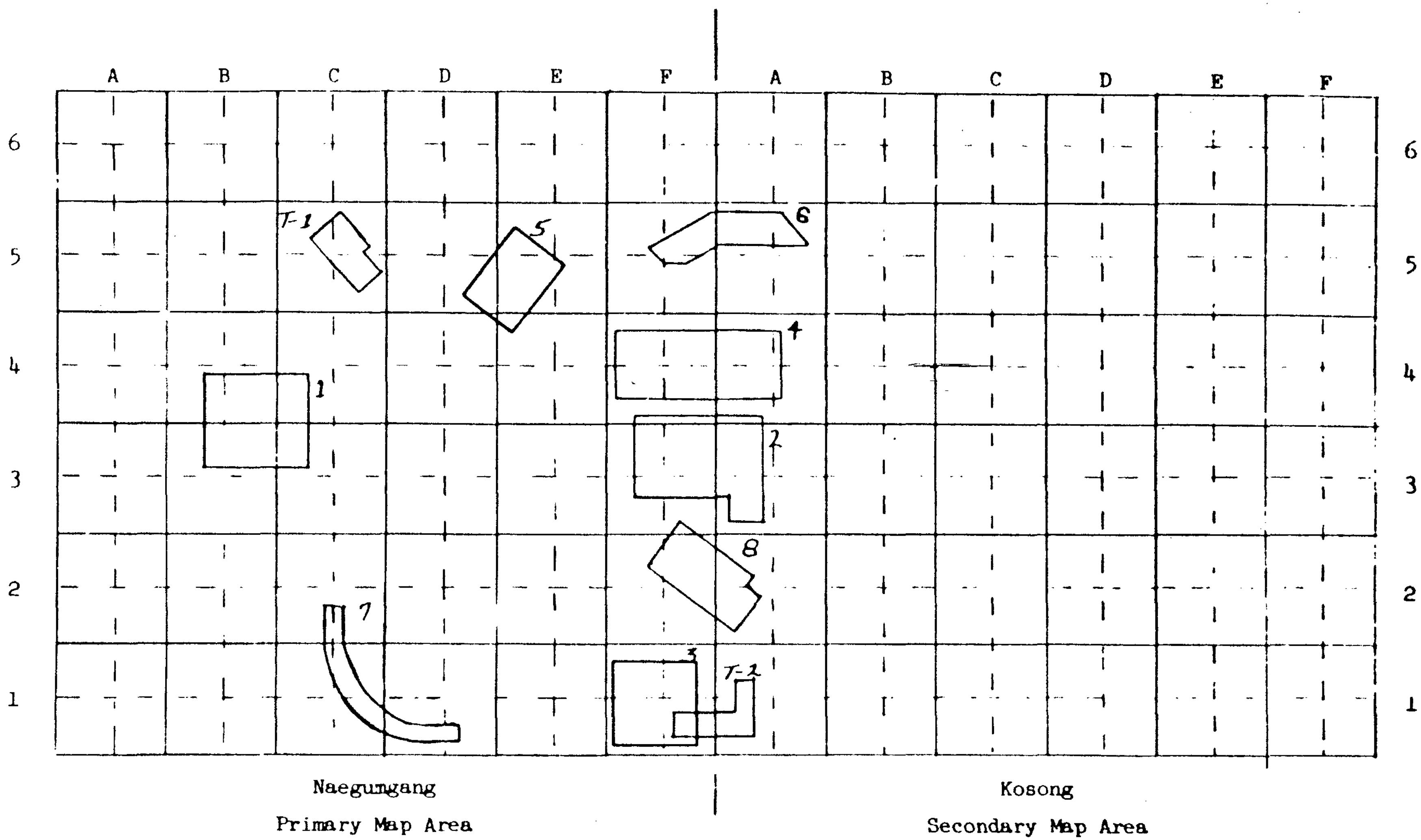


Figure C-6. Problems for Experiment 2 (Grid over each map area).

INDEXING EXPERIMENT

NAME: ______________________

EXP: SA or LA ______________

GRAPHIC TRAINING Accession No.	TEXTUAL TRAINING Accession No.
1. ______	1. ______
2. ______	2. ______
3. ______	3. ______
4. ______	4. ______

TEST Accession No.	TEST Accession No.
1. ______	1. ______
______	______
2. ______	2. ______
______	______
3. ______	3. ______
______	______
4. ______	4. ______
______	______

Figure C-7. Accession Number Recording Form Used by Each Subject

INDEXING EXPERIMENT

NAME: ____________________ DATE: ____________________

RANK: ____________________ AGE: ____________________

EXPERIENCE: ____________________ EXPERIMENTER: ____________________

SPECIALTY: ____________________

EXPERIMENT I

GRAPHIC

Training Scores

Prob. No.	Time
1	
2	
3	
4	

Test Scores

TEXTUAL

Training Scores

Prob. No.	Time
1	
2	
3	
4	

Test Scores

EXPERIMENT II

GRAPHIC

Training Scores

Prob. No.	Time
1	
2	

Test Scores

TEXTUAL

Training Scores

Prob. No.	Time
1	
2	

Test Scores

Comments by Subject: ____________________

____

Comments by Experimenter: ____________________

____

Figure C-8. Data Collection Form Used by Experimenter

Unclassified

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
*Information extraction from imagery						
*Laboratory facilities						
Tactical image interpretation facility (TIIF)						
*Information storage and retrieval						
*Computer-based image interpretation systems						
*Reference indexing methods						
Graphic indexing						
Textual indexing						
Map displays						

INSTRUCTIONS

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